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Upscaling laboratory results for water quality prediction at underground collieries in South Africa's Highveld Coalfields

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ABSTRACT

The prediction of future acidity and water quality is a key aspect of water management in mining environments. In this paper, different prediction techniques tested in an isolated underground compartment at a colliery in the Highveld Coalfield of South Africa are discussed. Considerations for upscaling these results are explained, and a methodology for upscaling is tested at this facility. Over 30 samples were collected around the compartment and through cored boreholes. These samples were tested using acid–base accounting tests, humidity cells, and mineralogy. From this, an integrated interpretation of potential water quality evolution was made, supported by detailed water quality sampling with the use of surface boreholes, stratified sampling underground, and pumped qualities over a period of two years. The results show that analytical tests play an integral role in water quality predictions at underground collieries. The results also show that, despite the vast differences between laboratory test conditions and the situation in the field, by taking site conditions into account to properly contextualise the results, improved predictions of expected water quality can be obtained.

1. Introduction

Acid mine drainage (AMD) is a widespread phenomenon affecting the quality of water at all South African collieries. It has been estimated that there are 10,000 km^2 of interlinked coal mining in the Mpumalanga coalfields alone (Van Vuuren, 2007), and that post-closure, these may add up to 600 tons of sulphate to the water regime per day (Grobbelaar et al., 2004). Techniques to determine the likely leachate quality are numerous, and have thus far been applied without uniformity throughout the African continent. Accurate prediction potentially offers the most cost-effective means of reducing the impact of AMD on the environment, with its associated costs, by allowing advanced planning for prevention and control (Price, 1998).

While methods to predict water quality changes for mine waste deposits are well-established, the prediction of water quality changes for underground mining has received less attention. Furthermore, the approaches used for coal and other minerals often need to be somewhat different (Kleinmann, 2000).

The methodology, results and discussion in the sections that follow highlight the prediction techniques commonly used for mine water quality, and apply these to a well-characterised underground mining compartment in the Highveld Coalfield of South Africa. Laboratory results are used to determine the likelihood of acidification, and also the expected water quality in the field. The challenges of upscaling standard hydrochemical tests and approaches to estimate the required parameters and include the hydrological aspects are illustrated in the case study. A comparison to observed water quality within the compartment highlights the important considerations in this specific case, and points to key considerations for wider application within the South African coalfields, and perhaps those further afield.

1.1. Techniques for the prediction of acid mine drainage

There are several methods that can be used to predict AMD. These range from static laboratory-based methods to kinetic laboratory methods and geochemical modelling. However, most importantly, the proper geochemical testing must be performed (McRae and De Vos, 2006). The greatest criticism of these methods is the vast differences between testing conditions and the field. In this paper, both the standard interpretation and interpretation taking field constraints into account are shown.

Acid–base accounting (ABA) is the most widely used static method. These tests are screening methods to determine the difference between the acid generating capability (AP) and the acid neutralising potential (NP) of a particular sample. The difference between these potentials can be calculated, and the net neutralising potential (NNP) and/or ratio of neutralising potential to acid generation potential (NPR) are compared with a predetermined value or set of values, to divide samples into categories that either

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require or do not require further determinative acid potential test work. Kinetic test work requires longer-term laboratory testing to determine the evolution of water quality over time, to thereby assess reaction rates and the likelihood of acidification.

One of the greatest challenges in these methods is the successful upscaling of results to field scale, and there should be due consideration of the factors that differentiate laboratory studies from true field conditions. Underground mining seldom involves such upscaling, and this paper outlines a suggested approach, based on the construction of a well-constrained hydrogeochemical conceptual model, to do this in South African collieries.

1.2. Study area

The selected compartment (called BC1 in this paper) lies in the Highveld Coalfield of South Africa. The mine lies between the towns of Secunda and Charl Cilliers in the Mpumalanga Province of South Africa (Fig. 1). BC1 is a relatively isolated compartment on the southern extent of present-day mining. It is separated from the rest of the mining by dolerite intrusions, which limit access and have removed much of the coal surrounding the compartment. Two distinct types of underground mines exist, namely above- and below-drainage mines. Below-drainage underground mines are located below the regional water table (Skousen et al., 2006). The distinction is important, since the infiltrating water in the latter can fill the mine voids, resulting in the O_2 deprivation of the pyrite in coal and associated minerals. This is a completely below-drainage mining compartment.

The three mining methods employed at the colliery include bord-and-pillar methods (59%), Stooping (30.3%), and longwall methods (10.7%). At BC1, the mining height varies between 2.8 m and 3 m. The area overlying the compartment was originally characterised by a fairly flat topography. The alterations to the natural topography due to subsidence are not considered significant. Rainfall measured at five rainfall stations in the proximity ranges from 542 mm to 822 mm/yr (1993–2001). Over the BC1 Compartment, the average annual rainfall has been determined to be in the order of 780 mm.

1.3. General geology

The Highveld Coalfield comprises sedimentary rocks of the Dwyka Formation and the Ecca Group of the Karoo Sequence. Deposits of diamictite, glacio-lacustrine varved siltstone, pebbly mudstones and fluvio-glacial gravel and conglomerates represent the products of continental Dwyka glaciations. Clastic sediments and coal overlie these rocks. The sediments were deposited in shallow marine and fluviodeltaic environments and the coal accumulated as peat in swamps and marshes associated with these sedimentary environments (Jordaan, 1986).

1.4. Water management

The compartment is maintained within a certain range of water elevations. For the operational duration of the mine, a water seal elevation of 1484.5 m above mean sea level is the maximum level to which the water level is allowed to rise due to safety considerations. Consequently, the water level fluctuates within a metre or more of this elevation. Control is maintained by abstraction from the compartment, based on visual observations by a responsible person, and water is pumped out at frequent, albeit irregular, intervals.

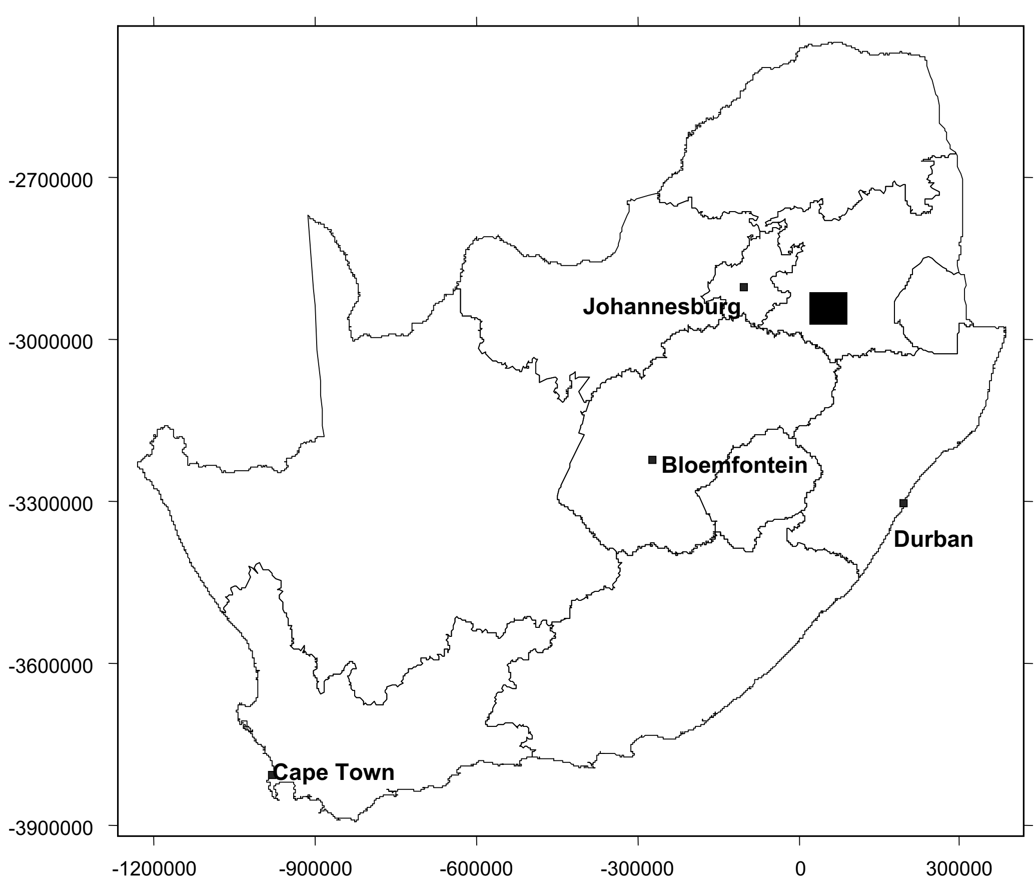

Fig. 1. Map of South Africa with study area shown as block to east of Johannesburg.